Behavioral Responses of Zooplankton to Thin Layers

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LONG-TERM GOALS

My long-term goal is to achieve a predictive understanding of the vertical distribution and migration of pelagic animals in the sea by assessing the behavioral and demographic responses of zooplankton and micronekton to their biotic and abiotic environment.

SCIENTIFIC OBJECTIVES

The primary scientific objectives of this project are:

1) To determine if zooplankton alter their vertical position and/or migration behavior in response to thin layers.

2) To determine the time course of such response (seconds–hours).

3) To determine how long after erasure of thin layers before the animal returns to a "normal" migration behavior.

4) To determine how these responses vary between species and across diverse taxonomic categories (e.g., ciliates, copepods, euphausiids, and larval fish).

APPROACH

My approach is to undertake a series of well replicated experiments on a broad range of zooplanktonic taxa, including copepods, larval fish, larval euphausiids, and ciliates. Our experimental apparatus consists of a series of six columnar tanks equipped with infra-red video cameras that continuously scan the full vertical range (210 cm) of each tank and thereby determine the vertical distribution of organisms over a several day period (Fig. 1). Each custom Plexiglas tank is fitted with eight sets of valves (one input and one outflow) spaced at intervals to allow for adding or withdrawing water samples for manipulation or analysis (e.g., nutrients, chlorophyll or ciliates). A natural light simulation system is comprised of a light source and a dusk/dawn simulation wheel made of increasing layers of neutral density blocking gel. The light source for filming is an infrared light-emitting diode (IR-LED). A video camera fitted with a macro/zoom lens is mounted in front of the tank. Zooplankters are seen as silhouettes and recorded on a VCR with a date/time recorder. This entire

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assemblage of camera, lens and IR-LED light source is mounted on a motorized linear bearing/rail system, and is run via a computer controlled timer. The vertical tank dimension of 210-cm provides a realistic scale for shallow water zooplankton such as copepods like Acartia (e.g., Bollens and Frost 1989, 1991, Bollens and Stearns 1992, Bollens et al. 1992, 1993, 1994) and larval herring (Speekmann et al. 2000, Lougee et al. In Revision,) and is within an order of magnitude for other coastal species such as larval euphausiids (Bollens et al. 1992). The six tanks are housed in a light- and temperature-controlled experimental room. The series of six tanks allows for adequate replication of treatments and controls within a given experiment.

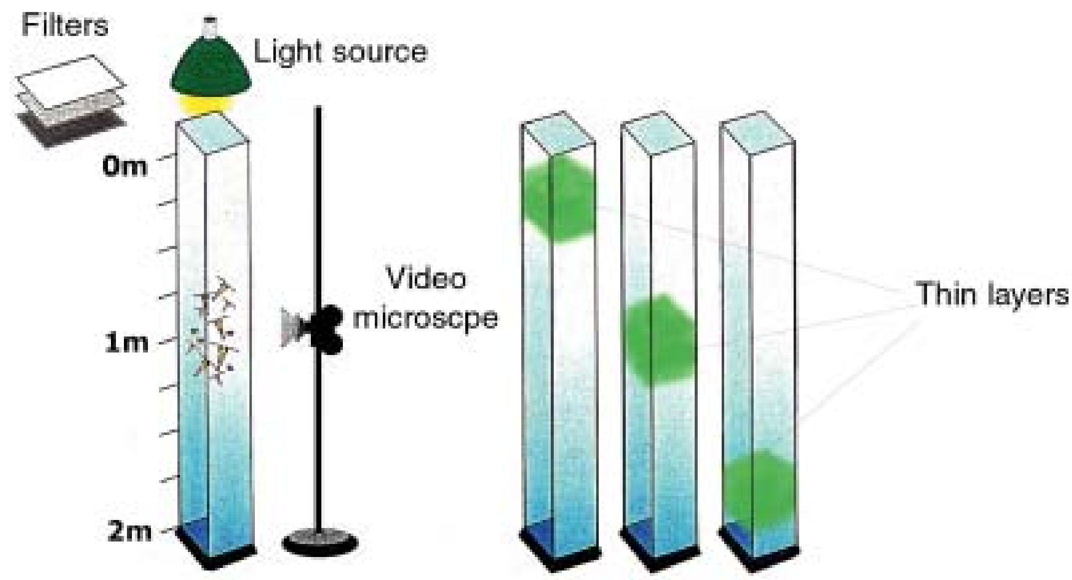

Figure 1. Two-meter high columnar tanks are illuminated by natural light simulators, which incorporate neutral density filters to adjust light intensity. The entire vertical extent of each tank, having one or more thin layers of phytoplankton at various depths, is repeatedly scanned and imaged with an infrared-sensitive video microscope to record zooplankton distribution.

Stratified water columns are formed in each tank by gently adding seawater of slightly different salinities. Thin layers of 10-cm or less can be established at any depth within the tanks and can be maintained for several days to weeks. Individual zooplankters of the same species and stage are sorted from live tows and placed in the tanks. Phytoplankton (or nauplii or ciliates) are injected into each layer through the appropriate valve(s). Zooplankton are then sampled for response to thin layers by determination of vertical distribution and possible migration using video microscopy as described above. Phytoplankton and ciliates are sampled less frequently (e.g., every 1-3 hrs) by collecting a small volume of water from each of the eight valves from each tank. The resulting data on vertical distribution of zooplankton and food can then be analyzed statistically (e.g., Bollens et al. 1994, Solow et al. 2000) to test for significant differences between treatments and/or controls.

WORK COMPLETED

We have achieved several significant accomplishments to date. First, we have deployed and tested our tank and video-microscope system under an increasing number and breadth of conditions. Second, we

have run experiments on the behavioral responses to thin layers of: the copepods Acartia spp. and Tortanus dextrilobatus; larval fishes (herring and top smelt); the ciliate Strombidium sp.; medusae of Aurelia aurita; the rotifer, Brachionus plicatilis, and brine shrimp, Artemia sp. Third, based on data generated from our tanks and video-microscope system, we revised two manuscripts on the related topics of zooplankton behavioral responses to haloclines (Lougee et al., In Revision) and ultraviolet radiation (Speekmann et al. 2000). Fourth, we revised and published a manuscript reporting a novel statistical approach for examining vertical distributions of plankton (Solow et al. 2000).

RESULTS

Our experimental tanks and video-microscope system has functioned extremely well under the full range of conditions outlined in our proposal. One example of our results of zooplankton behavioral response to thin layers, using the experimental apparatus described above, is that of larval herring aggregating into cm-scale layers of food (rotifers) (Fig. 2). This aggregation of fish within thin layers contrasts sharply with the more homogeneous distribution (and surface orientation) of the fish in the treatment with homogeneous distributions of salinity and food (Fig. 2).

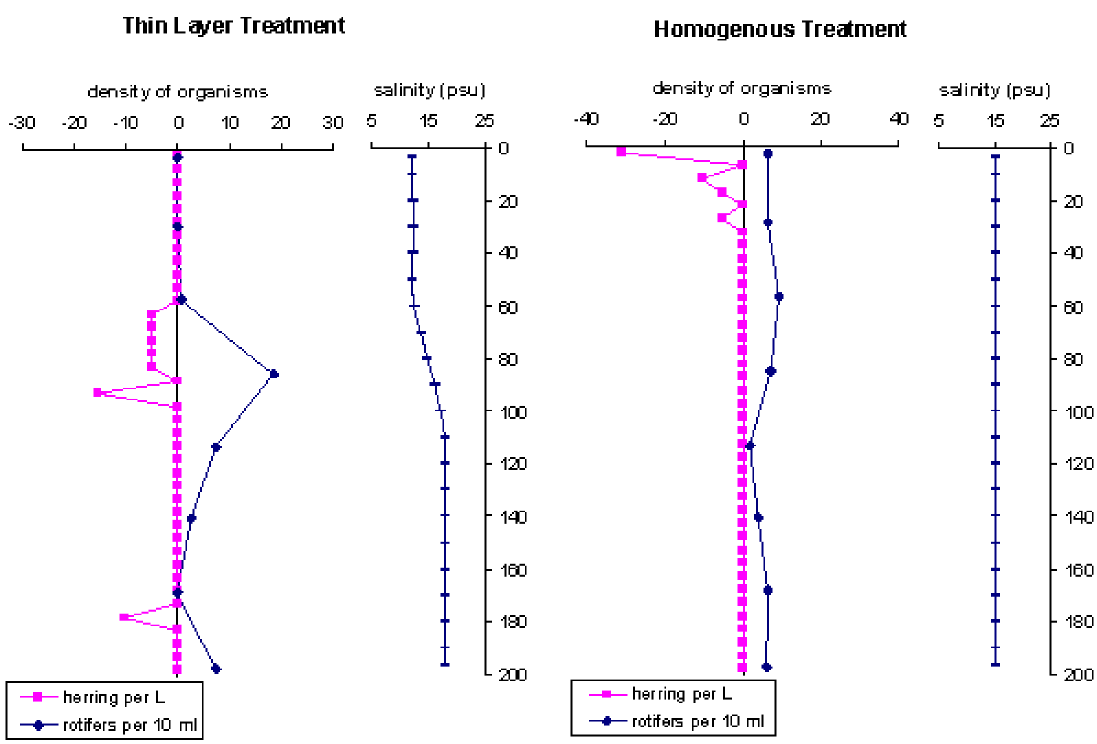

Figure 2: Representative vertical distributions of rotifers and herring larvae in a thin layer treatment vs. a homogenous treatment, on March 19, 2001, eight hours after establishing the treatments. The rotifers were sampled from valves spread 25cm apart. Herring larvae were sampled every 1cm, but binned into 5cm strata for presentation (Clay and Bollens, Unpublished).

Additional interesting and novel results have resulted form our related experimental studies on zooplankton behavioral responses to haloclines (Lougee 2000; Lougee et al., In Revision) and ultraviolet radiation (Speekmann 2000, Speekmann et al., 2000). For instance, some, but not all, taxa of zooplankton showed marked behavioral responses to halcolines of thickness (10-50 cm) and

magnitude (2-8 PSU) that occur in nature, often aggregating at or near the halocline (Lougee 2000; Lougee et al., In Revision). This has obvious implications for our studies of thin layers. Additionally, some crustacean zooplankton (e.g., Tortanus dextrilobatus) and ichthyoplankton (e.g., larval herring, Clupea harengus) showed a marked response to ultraviolet radiation by changing their vertical distribution and/or migration behavior (Speekmann 2000; Speekmann et al. 2000). These results provide additional, corroborating evidence in support of earlier studies (e.g., Bollens and Frost 1989, 1991, Bollens et al. 1992, 1993, 1994) that individual zooplankton can and do exercise flexible, plastic migration behavior in responding to their biotic and abiotic environment. The degree to which this is true for zooplankton responding to thin layers of food remains to be proven experimentally, although our preliminary results (described above and illustrated below) are intriguing.

Finally, a report of a novel statistical technique for testing differences between two vertical distributions of plankton (Solow et al. 2000) was published early in the 2001 fiscal year.

IMPACT/APPLICATION

Our results provide experimental evidence that zooplankton are able to sense the presence of thin layers of food and to actively migrate towards and aggregate within them. Our related experimental studies indicate that zooplankton can also sense haloclines and ultraviolet radiation and alter there vertical distribution accordingly. These findings represent an important contribution to the Thin Layers program, especially insofar as these are the only experimental studies providing evidence to support (or refute) the extensive field studies.

This research is relevant to Navy interests because zooplankton and micronekton dominate the scattering of sound in the water column at frequencies between 10 kHz and 10 MHz; the Navy must therefore be able to predict where and when sound scattering layers will occur. Moreover, this research is broadly relevant to oceanic biology, for depth selection is important not only in population biology and community ecology of zooplankton, but also in understanding the vertical flux of materials, nutrients and energy from surface waters to depth in the ocean.

RELATED PROJECTS

This research is relevant to virtually all of the many field studies previously and currently being undertaken within the “Thin Layers” program.

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